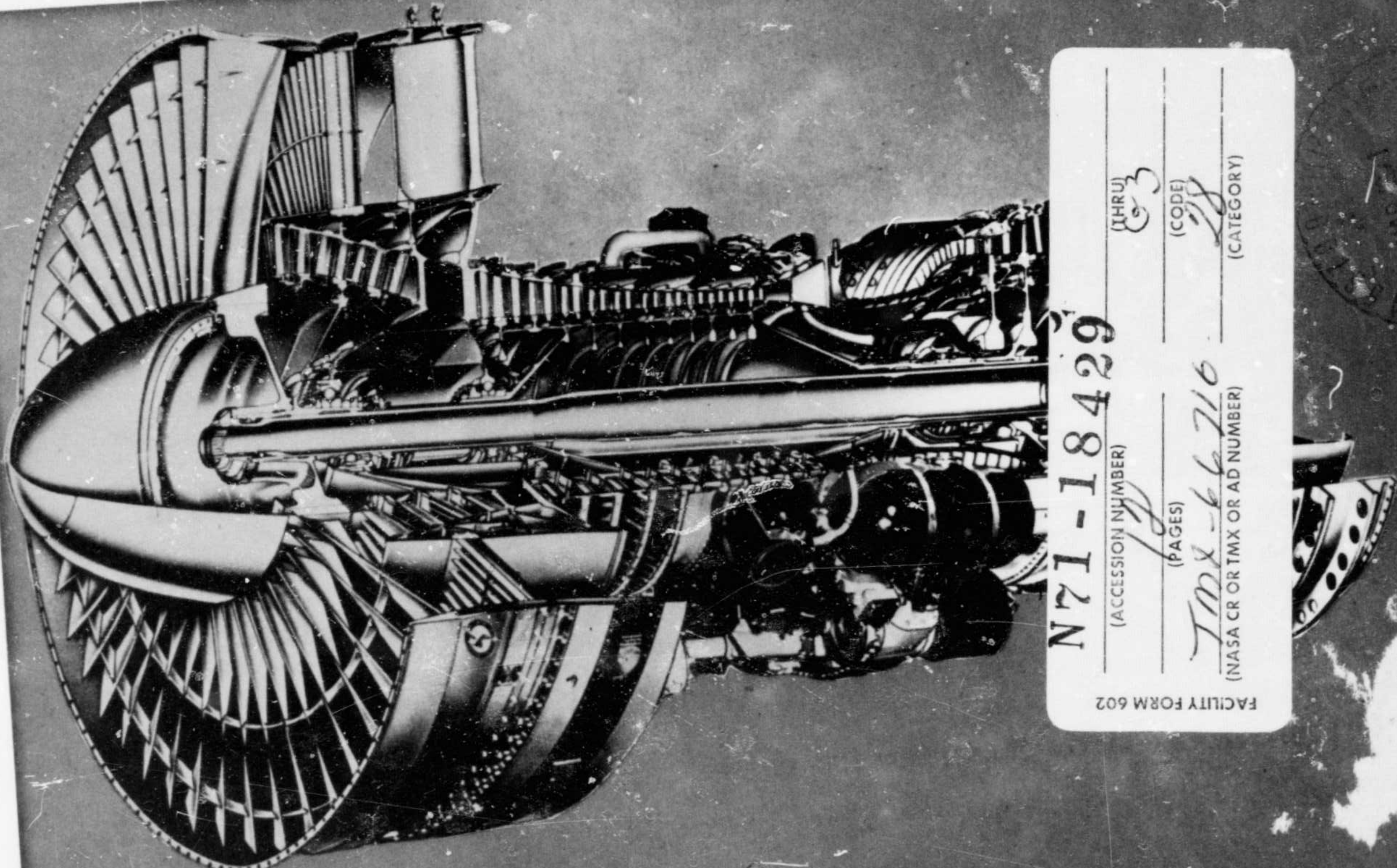

TURBOFAN ENGINE FOR SHUTTLE

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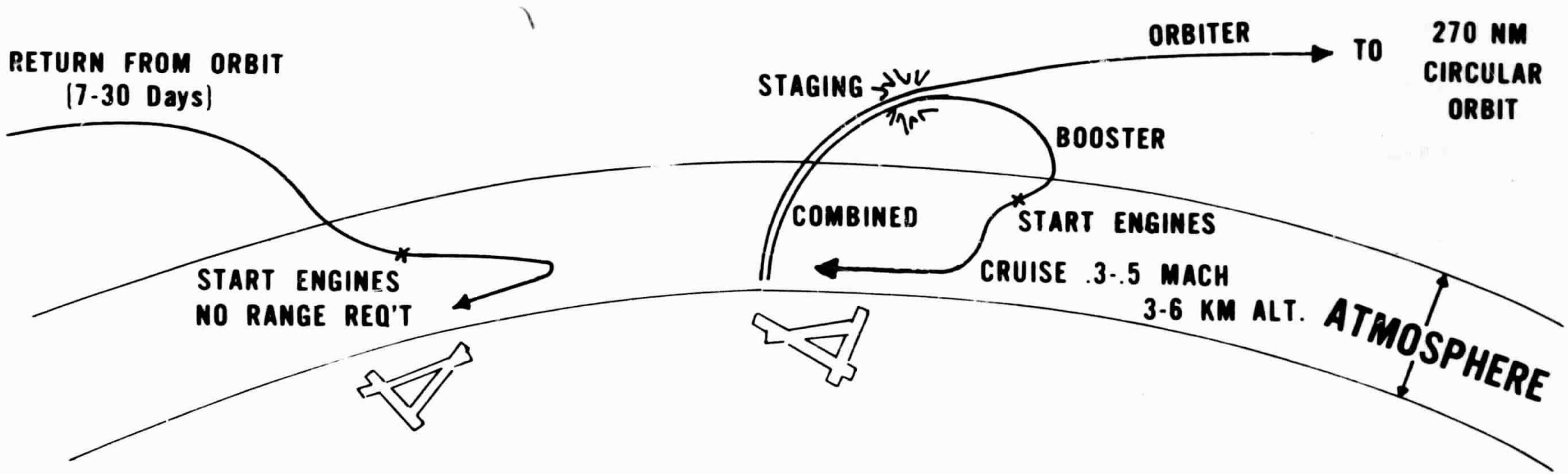
THE JET ENGINE IS REQUIRED TO COMPLETE THE FINAL PHASE OF THE REUSABLE EARTH TO ORBIT SHUTTLE FLIGHT. THE BOOSTER MUST RETURN ABOUT 500 KM TO BASE. THE ORBITER ENGINES ARE USED PRIMARILY TO MAINTAIN GLIDE SLOPE AND TO ALLOW GO-AROUND.

BY PROVIDING FLEXIBILITY OF LANDING SITES DURING NORMAL OPERATION AND UNDER EMERGENCY CONDITIONS, THE DOWN RANGE RESTRICTIONS OF EXPENDABLE LAUNCH VEHICLES ARE ELIMINATED. A LANDLOCKED COUNTRY CAN LAUNCH A SHUTTLE WITHOUT OFFENDING ITS NEIGHBORS.

JET ENGINES ALLOW SELF-FERRYING OF THE SHUTTLE VEHICLES AS NEEDED.

SPACE SHUTTLE - AIRBREATHING ENGINES



FUNCTIONS

BOOSTER

- FLYBACK TO BASE
- ALL AZIMUTH LAUNCH
- ABORT, GO-AROUND
- FERRYING

ORBITER

- IMPROVE LANDING FOOTPRINT
- ABORT, GO-AROUND
- FERRYING

JET ENGINES TODAY ARE HIGHLY SOPHISTICATED MACHINES BASED ON TWENTY FIVE YEARS OF INTENSIVE EFFORT ALL OVER THE WORLD.

THE DIFFERENCE IN JET ENGINE CHARACTERISTICS REQUIRED FOR BOOSTER AND ORBITER GIVE RISE TO TRADE-OFFS IN THE SEARCH FOR LOW COST AND COMMONALITY.

THE TOTAL THRUST REQUIRED FOR THE BOOSTER IS 4 TO 6 TIMES THAT NEEDED ON THE ORBITER AND THE ENGINES OPERATE FOR OVER AN HOUR INSTEAD OF THE 10 MINUTES OR SO IN THE ORBITER LANDING PATTERN.

THESE FACTS IMPLY THAT SPECIFIC FUEL CONSUMPTION IS OF PRIME IMPORTANCE ON THE BOOSTER, WHILE THE ENGINE THRUST TO WEIGHT RATIO IS MORE IMPORTANT ON THE ORBITER.

ON BOTH VEHICLES THE ENGINES NEED PROTECTION FROM THE VACUUM OF SPACE AND THE ENVIRONMENT DURING REENTRY BUT HEATING RATES AND DURATION ARE HIGHER ON THE ORBITER, AS IS THE VACUUM EXPOSURE.

BECAUSE THE ORBITER MAY SELECT ITS REENTRY TIME, ENGINE-OUT IS A LESS STRICT REQUIREMENT THAN WITH THE BOOSTER.

THE FACT THAT THE ENGINES ARE USED IN SUBSONIC FLIGHT ONLY ALLOWS SOME SIMPLIFICATION IN NOZZLES AND INLETS AS COMPARED TO HIGH PERFORMANCE MILITARY AIRCRAFT.

CHARACTERISTICS

BOOSTER	ORBITER
900,000 NEWTONS THRUST	150,000 NEWTONS THRUST
DURATION - HOURS	DURATION - MINUTES
LOW S.F.C. - HIGH T/W	HIGH T/W - LOW S.F.C.
NEEDS THERMAL PROTECTION - LESS	NEEDS THERMAL PROTECTION - MORE
SHORT VACUUM SOAK	LONG VACUUM SOAK
NEED ENGINE OUT - HIGH	NEED ENGINE OUT - LESS
SUBSONIC	SUBSONIC

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THE DESIRE TO HAVE ONE COMMON FUEL ABOARD IS BALANCED BY THE ADDITIONAL COST OF QUALIFYING ENGINES TO OPERATE ON LH_2. ALTHOUGH NUMEROUS DEMONSTRATIONS OF LH_2 FUELED JET ENGINES HAVE BEEN MADE, THERE IS NO OPERATIONAL APPLICATION TODAY.

DESPITE THE DIFFERENCES IN CHARACTERISTICS FOR ORBITER AND BOOSTER, COST CONSIDERATIONS ARE A STRONG DRIVER TOWARD A COMMON ENGINE. COST EFFECTIVENESS STUDIES WILL ALSO DETERMINE THE DEGREE OF MODIFICATION FEASIBLE FROM A BASELINE OF EXISTING ENGINES.

RELIABILITY DEMONSTRATIONS ARE EXPENSIVE AND THE SPLIT BETWEEN TEST STAND AND OPERATIONAL EXPERIENCE MUST BE FOUND.

BOTH TOTALLY SUBMERGED AND DEPLOYED TYPES OF ENGINE INSTALLATION MUST BE EXAMINED IN DEPTH. IN ADDITION THE PACKAGING OF BYPASS ENGINES AND STRAIGHT JET ENGINES DIFFERS WITH THE TYPE OF INSTALLATION.

THE FERRYING CAPABILITY CAN BE BUILT IN OR PROVIDED BY ADDITION OF A KIT. VARIOUS OPERATIONAL MODES AND WEIGHT PENALTIES MUST BE ASSESSED.

ENGINE TRADE-OFFS
CAPABILITY, COST

- FUEL - LH_2 VS. JP-4
- COMMONALITY - BOOSTER AND ORBITER
- DEGREE OF MODIFICATION EXISTING-ADVANCED-NEW
- DEMONSTRATED RELIABILITY
- SUBMERGED VS. DEPLOYED CONFIGURATION
- BYPASS VS. STRAIGHT JET
- FERRYING - KIT VS. BUILT-IN

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IN ADDITION TO TRADE-OFFS WHICH AFFECT THE JET ENGINES ALONE THERE ARE SYSTEM TRADE-OFFS INVOLVING THE JET ENGINES.

FOR EXAMPLE, THE PAYLOAD ADVANTAGE OF USING LH_2 RATHER THAN JP-4 IN THE ORBITER JET ENGINES MIGHT BE 1500 LBS. A PAYLOAD GAIN OF THE SAME MAGNITUDE IS POSSIBLE BY IMPROVING SPECIFIC IMPULSE OF THE MAIN ROCKET ENGINES BY 1 SEC. RELATIVE COST MAY WELL DICTATE SUCH CHOICES.

SIMILARLY, EXTENSIVE FERRYING USING LH_2 WOULD PRESENT AN EXPENSIVE LOGISTICS PROBLEM IN SETTING UP LH_2 FILLING STATIONS. AIRBORNE COST SAVINGS MUST BE WEIGHED AGAINST GROUND BASED COSTS.

IF THE GO-AROUND REQUIREMENT IS DROPPED AND MAINTENANCE OF GLIDE SLOPE SETS THE ORBITER ENGINE REQUIREMENT, IT IS POSSIBLE THAT THE FUNCTION CAN BE PERFORMED BY THE ROCKET ENGINES ON BOARD.

THE NATURAL DESIRE TO INTEGRATE ALL THE HYDROGEN-USING SUBSYSTEMS INTO ONE COMPLEX SYSTEM MUST BE WEIGHED AGAINST THE CHANCE THAT ONE SYSTEM CAN BE USED AS BACK UP FOR THE OTHER, IN CASE OF MALFUNCTION.

SYSTEM TRADE-OFFS

BOOSTER

IMPROVED ROCKET ENGINE I_{SP}

VS. CONVERSION OF JET ENGINES TO HYDROGEN.

FERRYING LOGISTICS-JP VS. H_2

ORBITER

- NO AIRBREATHER VS. VARIOUS AIRBREATHERS VS. MANEUVERING ROCKET ENGINE
- REDUNDANCY VS. RELIABILITY
- INTEGRATION OF FUEL SUPPLY

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BEARINGS AND SEALS WILL SEE UNCOMMON TEMPERATURE EXTREMES AND MAY BE SUBJECTED TO VACUUM SOAK OF 30 DAYS.

THE EMBRITTLEMENT OF NICKEL ALLOYS BY HYDROGEN GAS AFFECTS BOTH ROCKET ENGINES AND JET ENGINES.

RAPID AND DEPENDABLE STARTING AT HIGH ALTITUDE IS A MUST.

THE RANGE OF DELIVERY CONDITIONS REQUIRED FOR AIRCRAFT LH_2 PUMPS IS CONSIDERABLY GREATER THAN THAT NEEDED IN ROCKET ENGINES.

UNCOMMON AIRCRAFT ATTITUDES AND DEEPLY SUBMERGED INSTALLATIONS GIVE RISE TO EXPECTED INLET FLOW DISTORTIONS.

DEPLOYMENT OF LARGE JET ENGINES INTO A HIGH SPEED SLIPSTREAM IS HARDLY STATE OF ART.

SHUTTLE LONG LIFE AND RELIABILITY ARE THE BASIS OF COST EFFECTIVENESS. LIFE PREDICTION METHODS AND AN ADVANCED CHECKOUT AND MONITORING SYSTEM WILL BE BETTER THAN A KICK AT THE TIRES.

TECHNOLOGY AREAS

- LUBRICATION IN SPACE ENVIRONMENT
- HYDROGEN - MATERIAL COMPATIBILITY
- SENSING AND CONTROL OF ENGINE OPERATION
- HIGH ALTITUDE WINDMILL STARTING
- WIDE FLOW RANGE LH_2 PUMPS
- FLOW DISTORTION
- DEPLOYMENT
- LIFE AND RELIABILITY PREDICTION
- ON-BOARD CHECKOUT, MONITORING

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CURRENT PROGRAMS

*VEHICLE CONTRACTORS / IN-HOUSE MSC. MSFC } CONDUCT TRADE-OFFS. SELECT REPRESENTATIVE ENGINES. DETAIL INSTALLATION

*ENGINE CONTRACTORS -

EVALUATE FEASIBILITY AND COSTS OF:

- Modified Existing Engine
- Modified Advanced Engine
- All New Design

CONDUCT IN-DEPTH EXAMINATION OF TECHNOLOGY NEEDS

*IN-HOUSE. LEWIS CENTER

STUDY LH_2 FEED SYSTEM AND CONTROL TRANSIENTS ON SCALE MODEL ENGINE

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